J. F. Campbell
June 3. 1876.

By invitation of the President of the Royal Society went to the Observatory and got this report

REPORT

See page 16

OF

THE ASTRONOMER ROYAL

1877. — My observations returned.

TO THE

BOARD OF VISITORS

OF THE

ROYAL OBSERVATORY, GREENWICH,

Read at the Annual Visitation of the Royal Observatory, 1876, *June* 3.

REPORT OF THE ASTRONOMER ROYAL

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Read at the Annual Visitation of the Royal Observatory, 1876, *June* 3.

The Report which I now present is intended to exhibit the condition of the Royal Observatory on 1876, May 8; and to give its general history through twelve lunations, beginning with the Full Moon of 1875, May 20. The Report is closed at a somewhat earlier period than usual, as the number of subjects on which information is to be given has increased in the later years, and the leisure for writing is at the same time diminished.

I. Buildings and Grounds:—

I have often been struck with the exposed position of the Observatory, as regards the liability to burglary and theft; and have determined to make one place secure, in which, if necessary, valuable objects might be deposited. The small Manuscript Room, a separated portion of the Old Quadrant Room, having brick roof and iron door, required nothing but a proper lock on the door and iron bars on the window; these have been lately applied.

At the door from the front court to the staircase of the Octagon Room (the original entrance to the Observatory as erected by Sir Christopher Wren), a small porch-

shelter has been often desired. I propose to fix there a fan-roof of quadrantal form, covering the upper flat stone of the external steps. I scarcely need to say that I shall be careful to avoid interference with the venerable Tablet, whose noble and simple enunciation of the purposes of the Observatory has, I am persuaded, been most beneficial to its constant conduct.

The visitors will have remarked a wooden stage fixed upon the top of the Quadrant Room, for giving access to the light which illuminates the Collimating mark of the Altazimuth. Though necessary when the galvanic apparatus failed, it is now little used, the action of the galvanic induced current being uniformly successful.

In the Battery Basement, inconvenience arose and insulation was sometimes endangered by the position of the cells of galvanic batteries upon wooden shelves. They are now all placed upon shelves of rough glass.

A small water-hose is established in the Magnetic Observatory.

Of the various portable buildings for the observation of the Transit of Venus, some are left in their lonely positions for the use of voyagers who may accidentally visit those localities; some are deposited at Simons Town, and I am encouraged by the Hydrographer to hope that they will be returned in the current summer; those which have been brought to Greenwich have undergone numerous shifts. At present, one hut is at Chatham, and four at the Exhibition at South Kensington; others are on our grounds, or in the Reserved Ground of Greenwich Park.

Mr. De La Rue's scale of equal parts was suspended at the date of the last Report, in a vertical position. On taking photographs of it, by use of a photoheliograph planted in the grounds of the Royal Naval School, we found that the horizontal edges of the photographs of the plates were always indistinct, as if the building trembled vertically, or as if there was vertical irregularity of atmospheric refraction. On placing the scale upon the top of the Octagon Room in a horizontal position, the vertical edges (the only ones with which we had now to treat) were quite sharp, and we have had no farther trouble. We may now contemplate its early removal.

In the Magnetic Basement, it has been found necessary to extend, in the westerly direction, the bearing surface of the pier which supports one foot of the stand of the upper declination-magnet (as will be mentioned hereafter). This is done by placing a stout plank of slate upon the brick pier, one end of it projecting sufficiently beyond the edge of the pier, the other end being held downwards by a brass cramp whose lower end is fixed to the pier.

II. Moveable Property :—

On our moveable property of general character I have nothing to remark; it suffers in use, and is repaired, and goes through all the changes incidental to matters of that class.

Our astronomical instruments which were issued for use in the Transit of Venus expedition are all returned, with the exception of those that went to Kerguelen. These are still detained at Simons Town, together with some borrowed instruments, which I could much wish to restore to their owners, who so kindly acceded to applications for the loan of them. The instruments which have arrived have all been put in good order; among them was the portable Altazimuth, which had suffered from rust.

III. Manuscripts :—

The daily arrangement of manuscripts in the first degree, and the occasional advance to the next important step (which is greatly facilitated by the punching-system that I introduced long ago), are kept up with great regularity. A large quantity has lately been bound, in their usual orderly arrangement.

The insertion of the proper current Nos. upon the class-labels is completed.

The usual annual comparison of the bound manuscripts with the former Catalogue has now been effected. All are found, with a few exceptions which, I believe, can be explained.

Of the large mass of manuscripts now collected and arranged, a considerable portion naturally relates to the internal history of the Observatory,—material, disciplinarian, and scientific. But a very large part also relates to external science of many branches; and this may at some future time contribute in a most important degree to the authentic history of science during the middle of the present century.

IV. Library :—

Numerous additions have been made to the Library by presents from foreign scientific bodies; and some have been obtained by purchase. These latter transactions are now conducted through H. M. Stationery Office, and every application made by me to that department has received prompt and careful attention.

The usual annual comparisons of books with their Catalogue is completed; every book is found, or is accounted for.

V. Astronomical Instruments :—

The Transit-Circle is in very good condition; the principal repairs being the substitution of new micrometer-screws for the microscopes, and the renewal of the three middle wires, which were found broken on March 22.

In consequence of the discordance found between the results obtained when different parts of the screws of the microscope-micrometers were used, as explained in the last Report, the four supplementary microscope-micrometers (constructed for determining the division-errors), were mounted and read for all observations from 1875, June 15, to August 25. The results thus obtained were compared with those given by the six ordinary microscope-micrometers, and a table of corrections for each revolution and tenth of revolution of the latter micrometers was formed, on the assumption that the readings of the supplementary micrometers were sensibly correct, as they had been but little used. The corrections, which range from $-1''{\cdot}38$ to $+0''{\cdot}76$, indicate considerable wear in the screws; and on actual examination it was found that as much as one hundredth part of an inch had been worn away from some of the threads. The old screws were consequently discarded and new ones were made by Mr. Simms, which have been used regularly since the beginning of this year. As a check on the corrections found for the old screws, the readings of the four supplementary microscopes, mounted in the tubes for which they were originally made (at angular distances of 20° and 25° both from microscope A and from microscope B), have been taken regularly from 1876, January 9, to March 20, and their results compared with those given by the ordinary microscopes (with the new screws). The discordances are in every case small, and fall well within the limits of error of observation; from which it may be inferred that both sets of screws are sensibly free from periodic error. There is, however, a small systematic difference (amounting to $0''{\cdot}2$) between the Zenith Distances deduced from the two sets of microscopes, which, if not a mere chance-error, may perhaps be due to outstanding division-error,

affecting differently the Zenith-points used in the two cases respectively. It is to be remarked that the observations, on which these depend, are very restricted in their range; and that certain parts of the circle would fall habitually under the ordinary microscopes, whilst other parts would be used for the supplementary microscopes. The systematic difference in the case of the former comparison (with the old micrometer screws), amounts only to 0″·1, and has the opposite sign. A new investigation of the R—D correction, after the application of the correction for inequality of the micrometer-screws for 1874, gives almost exactly the same value of the variable term as before; but the constant term is increased to 0″·1, which appears to represent the effect of the systematic difference mentioned above. The resulting change in the co-latitude is insignificant, the corrected value for 1874 being 38°.31′.21″·52, whilst that formerly found was 38°.31′.21″·48; it is satisfactory, however, to find that the four close circumpolar stars now give very accordant results; the corrections to the assumed co-latitude from the observations of λ Ursæ Minoris, Polaris, Cephei 51, and δ Ursæ Minoris, being respectively +0″·04, 0″·00, −0″·12, and 0″·00. It is worthy of remark that the discordance, formerly found between the Zenith-points deduced from the Nadir-observation and those obtained from the mean of North and South stars, agrees sensibly with the correction corresponding to the part of the micrometer-screws used in the former observation, whilst for the supplementary microscopes the discordance is insensible. Its origin is thus clearly indicated. The R—D correction, however, would appear to depend on other causes.

A new determination of the coefficient of flexure was made on 1876, January 28 and February 1; the mean of the results is identical with the value formerly found.

The Sidereal Standard Clock is in good order.

The Chronograph has been cleaned since the last Report, and is now in excellent order. A pin lately gave way, which allowed two of the toothed wheels to separate, and the heavy weight fell; the injury to the instrument was however very trifling.

The Altazimuth is in good working order, though a little trouble has been occasioned lately by stiffness in the azimuthal motion. As the lower bearing of the vertical axis appears never to have been cleaned since the erection of the instrument, I have had the whole instrument raised, under the superintendence of Mr. Simms, and the accumulation of oil cleaned out. Small channels are now made, to permit the oil to reach the bearing-parts more readily.

The pivots of the horizontal axis are cleaned once in every lunation; the vertical circle and telescope being raised for that purpose.

The alteration in the position of the Collimating mark, alluded to in the last Report, has been carried out, and the determination of Collimation-error is now made

independently of star-observations. The gas-lighting apparatus provided by Messrs. Comyn, Ching, & Co., after some trouble occasioned by the breaking down of the induction-coil (the result probably of a thin coating of the induced-current-wire, which gave a more powerful induced current and less strength to resist it), has been brought into use, and observations of the collimating mark are now made on every observing evening. The practice of observing two stars, one high and the other low, has however been continued, though the low star is now only used for Zero of Azimuth, of which it is considered desirable to have a double determination.

For more delicate bisection of the Collimating mark, slow motions in Azimuth and in Zenith Distance have been applied.

No steps have been taken for mounting a collimator by which the inclination of the horizontal axis can be determined, the original process of observing the horizontal transit of a star of great elevation in both positions of the instrument being still preserved.

The Sheepshanks and Shuckburgh Equatoreals are in working order, and have been used for occasional phenomena. The former is found very useful for practice of Supernumerary Assistants in observing by eye and ear; and, to facilitate these observations, the coarse wires of the transit-eye-piece belonging to this instrument have been replaced by spider-lines.

The Great Equatoreal is in excellent order. Some small repairs have been required in the driving clock, and it now gives perfect satisfaction.

It is occasionally necessary to clean the large object-glass; and the removal of the compound glass from its cell, the separation of the two lenses, and the restoration of all to their places, are somewhat hazardous. Mr. Simms, at my request, has prepared a plan of mechanism, by which all these movements will be effected by screw-motion; and I propose to bring it into action as early as possible.

An alarm of fire, on a part of the equatoreal frame, arose lately from a singular cause. The wire covered with gutta-percha, by which the current of induced galvanism is carried from the inducing coil of the spectroscopic apparatus to the eye-piece of the telescope, passes up to the northern support of the equatoreal and down along the polar axis. A very small leakage of the wire apparently allowed sparks to pass to the iron work, and a very small leakage from a neighbouring gas-tap allowed a small jet of gas to pass, which was inflamed by the sparks. After burning unperceived for several hours, it set fire to the gutta-percha covering of the wire, and the flame was propagated downwards on both branches, when it was discovered and extinguished by Mr. Maunder. No further mischief was done.

The adjustment of the Spectroscope has occupied a good deal of attention during the past year. With a view to correcting the astigmatism of the prisms, some of

them have been re-worked by Mr. Hilger, and, as it appeared probable that the cementation with Canada balsam produced some strain, castor-oil was temporarily substituted, without however producing any improvement. The plan ordinarily adopted in spectroscopes, of reflecting the pencil of rays into the lower tier of the train of prisms, by means of a right-angled-prism, and viewing the spectrum by a second telescope, was also tried, but with no better results; there being a slight amount of stray light on one side of each bright line in the spectrum viewed. This false light was ultimately found to be caused by reflection from the base of the prisms, the deviation of the pencil in passing through the half prism, with which the train commences, being 5° greater than it should have been, probably in consequence of a greater density in the flint-glass. The effect of this was to make the pencil of rays fall unfairly on the train of prisms, causing loss both of light and of definition, especially with great dispersive power. When this defect was corrected, by altering the angles, the definition was found to be very fine indeed, even with such a high power as 50. It is still found necessary to correct the astigmatism of the prisms by a cylindrical lens near the slit, which is readily done; the definition in both planes is then found to be perfect. The false light in the collimator, which at first gave some trouble, has been destroyed by giving a slight excentricity to the concave (or Barlow) lens near the slit, so that the axis of the pencil is bent in passing through the lens. This plan has some incidental advantages over the alternative of tilting the lens, and it has therefore been adopted, though the other arrangement gave equally satisfactory results. A concave lens has also been applied to the small viewing telescope, to increase the magnifying power, which was found to be hardly sufficient. An ingenious form of bright-line-micrometer has been applied to this telescope by Mr. Hilger, and the accuracy with which lines in the faint spectra of stars can be measured is found to be greatly increased by this improvement.

The Sprengel air-pump has given some trouble from its fragile nature, and some rather extensive repairs have been required.

The adjustments and repairs of the spectroscope and the air-pump have necessarily been attended with much expense.

A photographic camera (for occasional use) has been prepared, in such a form that it can be adapted to the rods which carry the spectroscope; thus avoiding the necessity for removing the spectroscope-barrel.

The Reflex-Zenith-Tube is in a satisfactory state. The wires, which are necessarily somewhat exposed, were recently found broken; they have been replaced by Mr. Simms.

The Kew Photoheliograph has been dismounted and returned to Kew Observatory; the Transit-of-Venus Photoheliograph, returned from New Zealand having been erected in its place. Before the Kew instrument was sent away, some photographs

of Mr. De La Rue's scale were taken with it, to determine its distortion as compared with that of the Transit-of-Venus Photoheliographs.

VI. Astronomical Observations:—

In the logical order of subjects of Meridional Observations, the first place is to be given to Stars. The number of our Fundamental Stars or Clock Stars is 215, and whenever the sky is clear some of these are observed. When the weather permits, a long series is observed; no inferences being drawn for the correction of the Right Ascensions of Fundamental Stars unless the series extends through six hours. The Circumpolar Stars are observed when practicable, below the pole as well as above it, although these observations usually fall in different seasons. Other stars, in lists from miscellaneous sources, as stated in the four last Introductions, are observed when opportunity serves.

We have taken no part in the observations of Zones.

The Sun, the interior planets, and the large exterior planets passing the meridian before 15^h, are observed every week-day; the small planets passing before 13^h are observed on week-days in the first half of each lunation (the other half being effectually secured under the administration of M. Le Verrier).

The Moon is observed, when visible, at meridian passage on every day, without any exception; and every opportunity is taken for observing her semi-diameter both in R. A. and in N. P. D., the proper days having been previously arranged by calculation.

The number of small planets has now become so great, and the interest of establishing the elements of all their orbits so small,—while at the same time the light of all those lately discovered is very faint, and the difficulty and doubt of observation greatly increased,—that I have begun to think seriously of limiting future observations to a small number of these objects. A German society proposes to observe, in the next year, among the planets whose elements are known most accurately, a list of seventeen planets, including all which are sufficiently bright to be observed with few chances of mistake, and a sufficient number possessing the various characteristics of small and large inclinations and excentricities, and proximity to Mars and to Jupiter. This proposal appears to me to be probably worthy of attention at Greenwich.

With the Altazimuth, the Moon and corresponding stars have been observed, without intentional loss of a day on which she was visible. The number of observations for her diameter (a fundamental element for reduction of every observation) is scarcely sufficient. I hope to increase them in future.

The number of observations made from 1875, May 20, to 1876, May 8, is given in the following statements :—

With the Transit-Circle :

Transits, the separate limbs being counted as separate observations	3,185
Pairs of observations of the nearly vertical wires of the Reversed Telescopes	288
Reciprocal observations of the nearly vertical wires of the Reversed Telescopes	334
Reflexion-observations of the central wire	363
Circle-observations, each requiring a separate reading of the six, four, or ten microscope-micrometers	3,374
Reflexion-observations of the zenith-distance wire (included in the number of circle-observations)	363
Reflexion-observations of stars (similarly included)	368

With the Reflex-Zenith-Tube :

Pairs of observations of γ Draconis, the instrument being reversed between the observations	39
Single observations	5

With the Altazimuth :

Azimuths of the Moon and Stars	791
Azimuths of the Collimating-mark	586
Zenith-distances of the Moon	367
Zenith-distances of the Collimating-mark	360
Zenith-distances of Stars for clock-error	2

The number of complete observations of the Moon near to her conjunction with the Sun is :—

On days when the Moon passed the meridian between 21^h and 22^h

Mean Solar Time			4
,,	,,	between 22^h and 23^h	2
,,	,,	between 23^h and 24^h	0
,,	,,	between 0^h and 1^h	0
,,	,,	between 1^h and 2^h	2
,,	,,	between 2^h and 3^h	5

The following comparison shows the number of places of the Moon observed with the Transit-Circle and Altazimuth respectively :—

With the Transit-Circle, 88, or 7·3 per lunation.
With the Altazimuth, 180, or 15·0 per lunation.

The following is the number of measures of the Moon's diameter :

With the Transit-Circle, 4 in R.A., 7 in N.P.D.
With the Altazimuth, 5 in Azimuth, and 17 in Zenith-distance.

The observations of occultations of stars by the Moon have been 9 in number; namely, 6 disappearances and 3 re-appearances. Of Jupiter's satellites, 13 phenomena have been observed. The instruments usually employed for these observations, sometimes simultaneously, are the Great Equatoreal and the Sheepshanks Equatoreal.

The partial eclipse of the Sun in September last was observed in the same manner as that of the preceding October, by measures of intervals of cusps, in R.A. and N.P.D.

Availing ourselves of an Ephemeris of Saturn's satellites published by Mr. Marth in the Astronomische Nachrichten, we have made measures of their distance and direction from the planet's body on the following days, included between 1875, September 14 and November 15 :—

Japetus on 11 days.
Titan „ 20 „
Rhea „ 20 „
Dione „ 13 „
Tethys „ 13 „

VII. Reduction of Astronomical Observations :—

On May 8 the reductions were in the following state :—

For Meridional Transit Observations :

Observed transits are corrected for instrumental errors, and clock-times of transit over the true meridian are prepared, to . 1876, April 29.
Clock errors and rates are applied, and apparent right-ascensions from observation are formed, to . . . . . April 28.
Reductions of apparent places of stars, to mean places on January 1 are prepared, to . . . . . April 28.
The two last-mentioned elements are combined, to form mean R. A. on January 1 of stars, from daily observation, to . April 28.
Mean solar times of observation of Sun, Moon, and Planets, are prepared, to . . . . . April 28.
Corrections for defective illumination of the limbs of Moon and Planets are prepared, to . . . . . April 28.

The Personal Equations in observation of transits during the year 1875 have been investigated; there is little change among the principal observers since 1874.

By comparison of the results for R. A. of circumpolar stars, as observed above the pole and below the pole, we do in fact check two different elements; one is, the general accuracy of the system of the corrections for collimation; the other is, the general correctness of the assumed difference of R. A. between opposite groups of stars. And I am convinced, by examination of the results to the end of 1875, with this view, that there is no sensible or certain error in either of these elements.

For observations with the Meridional Circle:

Means of readings of microscope-micrometers are taken, and corrections are applied for defects of micrometer-screws, and for reading of telescope-micrometer, error of graduation, flexure, inclination of wire, and zenith-point, in order to form apparent zenith-distances, to . . . . . 1876, April 29.

True geocentric north polar distances are formed by application of refraction, parallax, and colatitude, to . . . . . April 29.

Reductions of apparent N. P. D. of stars, given by daily observations, to mean N. P. D. 1875, January 1, are applied, to . March 18.

Corrections are applied for defective illumination of limbs of Moon and Planets, to . . . . . April 29.

No alteration has been made in the refractions, which are the same as those introduced in 1868.

The corrections for error of micrometer-screws have been applied to the N. P. D. of all stars in the Star-Ledgers and Catalogue both for 1874 and 1875, and to the N. P. D. of all objects in the Planetary Results for 1875.

The R—D investigation has been re-computed for 1874, after applying these corrections; the value found differs little from that previously deduced. The correction for the error of the micrometer-screws during the year 1874, and of a small mistake in computation, has slightly altered the inferred value of the co-latitude from $38^{\circ}.31'.21''{\cdot}35$, as stated in the last Report, to $38^{\circ}.31'.21''{\cdot}52$. The labour of correcting reductions for the error of micrometers has greatly retarded the reductions for 1875; and I am not able at present to state the 1875 co-latitude.

The calculations for position of Ecliptic and for errors of planetary tables are not yet completed for 1875.

Preparations are begun for forming a Catalogue of Stars, based on all the observations commencing with 1868. I have not decided whether it shall terminate with 1875 or with 1876.

The observations of γ Draconis with the Reflex-Zenith-Tube are reduced to the close of 1875.

The following is the state of reduction of the Altazimuth observations:—

For azimuths, true azimuths are formed by the combination of mean of microscopes, correction for level, collimation, and azimuth-zero, to . . . . . 1876, March 25.

For zenith-distances, true Greenwich zenith-distances, corrected for refraction and parallax, are formed, to . . . . April 23.

Corresponding tabular azimuths and zenith distances are formed, to . . . . . April 23.

Apparent errors of Moon's tabular R. A. and tabular N. P. D. are computed, to . . . . . March 25.

Apparent errors of Moon's tabular Longitude and tabular Latitude are computed, to . . . . . March 25.

The observations of the Occultations of Stars by the Moon are completely reduced.

The observations of the Solar Eclipse of 1875, September 28–29, made with the Great Equatoreal, are completely reduced in the same manner as those of the Eclipse of 1874, adopting corrections found for the semidiameters of the Sun and Moon from preceding eclipses. It was possible to observe this eclipse with the meridional instrument, and for reduction of that observation the semidiameter of the Sun found to apply to that instrument was employed.

The micrometer measures of Saturn's Satellites made during the past opposition with the Great Equatoreal have been completely reduced.

VIII. Spectroscopic and Photographic Observations:—

The Sun's chromosphere has been examined with the Spectroscope on 30 days, and the prominences mapped out, whenever any were found. During the winter months this work has been almost entirely interrupted by bad weather and the low altitude of the Sun, as well as by the necessity for making the various modifications in the Spectroscope, mentioned under the head of Astronomical Instruments. The average number of prominences has been very small during the past year, but a very marked increase both in number and size is shown in the recent observations.

Some measures of the width of the D lines on different parts of a Sun-spot, and a set of measures of the width of the principal Fraunhofer lines, have been taken; the latter with the powerful Spectroscope kindly lent by Mr. Spottiswoode.

One hundred and twenty-six measures have been made of the displacement of the F line in the spectra of 20 stars as compared with hydrogen, 15 of the displacement of the *b* lines in the spectra of 6 stars as compared with magnesium, and two of the displacement of the D lines as compared with sodium. Sixteen measures of the F line in the spectrum of the Moon as compared with hydrogen give a displacement corresponding to a motion of less than two miles a second, which seems to show that the method of comparison now adopted is free from systematic error; and this is supported by the manner in which motions of approach and recession are distributed among the stars examined on each night of observation. The results recently obtained appear to be on the whole as consistent as can be expected in such delicate observations, and they support in a remarkable manner the conclusions of Dr. Huggins, with regard to the motions of those stars which he examined.

The single-prism-Spectroscope has been occasionally used for mapping out the spectra of planets and stars. The remaining spectroscopic work has consisted of measures of the Fraunhofer lines in the Solar spectrum, and of the width of the hydrogen, magnesium, and sodium lines with varying width of slit, for determination of the scales to which the various measures have been referred.

Photographs of the Sun have been taken with the Photoheliograph on 182 days; and of these 350 have been selected for preservation. A large number of these show a complete absence of spots, though faculæ are commonly present. On one of the photographs, which was accidentally exposed while the drop-slit was being drawn up, there appears to be a faint image of a cloud-like prominence close to the Sun's limb, though the exposure probably only amounted to a fraction of a second. A prominence of unusual brilliancy was seen with the Spectroscope about the same time and in the same position with reference to the Sun's limb.

Photographs of some double stars and of the Moon have been taken with the Great Equatoreal, and some trials have been made in photographing the Solar spectrum and that of magnesium.

IX. Reduction of Spectroscopic and Photographic Observations:—

All observations with the Spectroscope have been completely reduced; the measures of lines in the spectra of elements being converted into corresponding wave-lengths, and the observations of displacement of lines in the spectra of stars being reduced so as to exhibit the concluded motion in miles per second, after applying a correction for the earth's motion.

As regards the Photographic reductions:—

All groups of Sun-spots and faculæ have been numbered, and the dates of their first and last appearances entered up to the present time. Areas of spots have been measured, in duplicate, to Photograph 775 on 1875, September 16, and the measures have been reduced to millionths of the Sun's visible hemisphere, to 1874, December 31.

Areas of faculæ have been measured to Photograph 777 on 1875, September 27, and the means have been reduced to millionths of the Sun's visible hemisphere, to 1874, December 31.

The sums of the areas have also been taken for each group and for each day.

X. Magnetical and Meteorological Instruments:—

The following are the Magnetic instruments at present in use:—The upper Declination-Magnet with Theodolite, the Dip-Instrument, and the Unifilar-Deflexion-Instrument, for eye observation of the absolute values of the magnetic elements; the Lower-Declination-Magnetometer, the Vertical-Force-Magnetometer, and the Horizontal-Force-Magnetometer, for photographic registration of their relative changes; and the Earth-current apparatus. The Meteorological instruments are,—One standard Barometer and three pairs of standard Thermometers (dry-bulb and wet-bulb) for eye observation; barometer, and dry-bulb and wet-bulb thermometers for photographic registration; six pluviometers, at different elevations, read by eye, and two self-registering; two self-registering anemometers (Robinson's and Osler's); and various electrometers for observation of atmospheric electricity. To these have been recently added an ozone box, and a new form of actinometer invented by J. F. Campbell, Esq., and kindly lent by him for experiment. The instruments generally have been cleaned as usual by Mr. Simms, and are all in good order.

When the Magnetic Observatory was erected in 1837, its sides were planned, as nearly as was practicable, parallel and perpendicular to the Magnetic Meridian of that date, and the Central Theodolite and the Upper Declination-Magnetometer viewed by it were both in the line passing along the center of the N. and S. arms of the building. Arrangement was made, in the mounting of the magnet, for a shift east or west of several inches. But in the considerable change of the Magnetic Meridian since that date, it has become necessary (for proper view of the magnet by the theodolite) to move the magnet westwardly to a greater distance than could be given by the arrangement in its mounting. The whole frame, therefore, supporting the magnet has been shifted; and, to provide footing for one of its legs, a cap has been placed upon a pier in the Magnetic Basement, in the manner described in Section I.

The new Standard thermometer, alluded to in the last Report, has been received from the Superintendent of the Meteorological Office; and a new pair of dry-bulb and wet-bulb thermometers have been procured from Messrs. Horne and Thornthwaite, the wet-bulb thermometer formerly used having been accidentally broken. A rain-gauge has been placed on the Thames Police ship "Royalist."

The electrical instruments have been cleaned by Messrs. Horne and Thornthwaite, and a new dry-pile apparatus has been supplied, which however is not found to act with certainty. I am in hopes of receiving shortly an Electrometer on Sir W. Thomson's plan, for photographic registration of atmospheric electricity, which will supersede the dry-pile apparatus.

The Astronomer Royal having undertaken to register the hours of sunshine in comparison with the number of hours the sun is above the horizon, some interesting results have been obtained. Thus last week the sun was above the horizon 69.3 hours, but his light was intercepted, and he only shone on London 9.3 hours: four days not at all; Sunday, 5.3 hours, Friday 3½ hours, and Saturday half an hour.

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nuous photographic records with the
ns with the three magnetometers
e zeros of the photographic curves,
magnetic instruments for absolute
ometers, and rain-gauges at certain

olite for zero of azimuth, once or
Magnetic Force is determined with
p is usually observed two or three
ne last-named observation has been
of level of the instrument, which is,
ly as possible. In the course of the
n our Standard, at the request of the

XII. Reduction of Magnetical and Meteorological Observations:—

The theodolite observations of stars, giving zeros of azimuth for the Declination-Magnet, are reduced to the last observation, and the absolute declination deduced to the end of last year. The telescope observations of the Horizontal-Force-Magnet are reduced to the present time; those of the Vertical-Force-Magnet to December 31. These determinations give the base-lines for the ordinates of the photographic curves.

As regards the Photographic reductions:—

All groups of Sun-spots and faculæ have been numbered, and the dates of their first and last appearances entered up to the present time. Areas of spots have been measured, in duplicate, to Photograph 775 on 1875, September 16, and the measures have been reduced to millionths of the Sun's visible hemisphere, to 1874, December 31.

Areas of faculæ have been measured to Photograph 777 on 1875, September 27, and the means have been reduced to millionths of the Sun's visible hemisphere, to 1874, December 31.

The sums of the areas have also been taken for each group and for each day.

X. Magnetical and Meteorological Instruments:—

The following are the Magnetic instrum
nation-Magnet with Theodolite, the Dip
Instrument, for eye observation of the al
the Lower-Declination-Magnetometer, the
Horizontal-Force-Magnetometer, for photogr
and the Earth-current apparatus. The Met
Barometer and three pairs of standard Ther
observation; barometer, and dry-bulb and
registration; six pluviometers, at different
registering; two self-registering anemometer
electrometers for observation of atmospheric
added an ozone box, and a new form of actin
and kindly lent by him for experiment. The
as usual by Mr. Simms, and are all in good or

When the Magnetic Observatory was erected
as was practicable, parallel and perpendicular
and the Central Theodolite and the Upper Dec
both in the line passing along the center of the N
ment was made, in the mounting of the mag
inches. But in the considerable change of the Magnetic Meridian since that date, it has become necessary (for proper view of the magnet by the theodolite) to move the magnet westwardly to a greater distance than could be given by the arrangement in its mounting. The whole frame, therefore, supporting the magnet has been shifted; and, to provide footing for one of its legs, a cap has been placed upon a pier in the Magnetic Basement, in the manner described in Section I.

The new Standard thermometer, alluded to in the last Report, has been received from the Superintendent of the Meteorological Office; and a new pair of dry-bulb and wet-bulb thermometers have been procured from Messrs. Horne and Thornthwaite, the wet-bulb thermometer formerly used having been accidentally broken. A rain-gauge has been placed on the Thames Police ship "Royalist."

The electrical instruments have been cleaned by Messrs. Horne and Thornthwaite, and a new dry-pile apparatus has been supplied, which however is not found to act with certainty. I am in hopes of receiving shortly an Electrometer on Sir W. Thomson's plan, for photographic registration of atmospheric electricity, which will supersede the dry-pile apparatus.

XI. Magnetical and Meteorological Observations:—

The observations under this head consist of continuous photographic records with the self-registering instruments, and of eye-observations with the three magnetometers taken four times each day, for determination of the zeros of the photographic curves, together with occasional observations of the other magnetic instruments for absolute determinations, and readings of the barometer, thermometers, and rain-gauges at certain hours of the day.

A circumpolar star is observed with the theodolite for zero of azimuth, once or twice a month; the absolute measure of Horizontal Magnetic Force is determined with the unifilar instrument once a month; and the dip is usually observed two or three times a week. Since the beginning of this year the last-named observation has been regularly corrected for the small outstanding error of level of the instrument, which is, however, always left adjusted to verticality as closely as possible. In the course of the year several thermometers have been compared with our Standard, at the request of the Warden of the Standards and of Dr. Hime.

XII. Reduction of Magnetical and Meteorological Observations:—

The theodolite observations of stars, giving zeros of azimuth for the Declination-Magnet, are reduced to the last observation, and the absolute declination deduced to the end of last year. The telescope observations of the Horizontal-Force-Magnet are reduced to the present time; those of the Vertical-Force-Magnet to December 31. These determinations give the base-lines for the ordinates of the photographic curves.

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The time scales for the Declination, Horizontal Force, and Vertical Force, as well as for the Earth-currents, are complete to the end of 1875, and new base-lines for the Declination are laid down for 1875; the base-line-values for the Horizontal Force are entered on the sheets to the end of last year. The hourly ordinates of the curves of Declination are read out for 1875; those of the Horizontal Force and Vertical Force are not yet done.

Taking the scale of magnetic disturbance which I have adopted in memoirs in the Philosophical Transactions, the number of disturbed days in 1875 is only two. For these days the ordinates are to be measured for all the salient points of the curve; no further reduction has been made of these numbers since 1857. For the other days, pencil curves are being drawn, smoothing down the principal inequalities; and their ordinates are being measured for every hour. These measures will be used to form tables of diurnal and other inequalities to the end of 1875.

The absolute measures of horizontal magnetic force are prepared to the end of 1875; thedips, as usual, are reduced to the last observation.

The following are the principal results for 1875:—

Mean westerly declination (approximate) .	19°. 21′.
Mean horizontal force	3·893 (in English units). 1·795 (in Metric units).
Mean dip	67°. 41′. 5″ (by 9-inch needles). 67. 42. 15 (by 6-inch needles). 67. 43. 34 (by 3-inch needles).

No measures have been made, and no theoretical results deduced, from the photographic curves given by the earth-current wires in their present position.

The following is the state of the meteorological reductions:—The eye observations are corrected for instrumental errors, and the dew point and degree of humidity are computed to the present day. Time-scales and the values of the base-lines are entered to the end of last year.

The vane of Osler's anemometer made, in the year 1875, 11 complete revolutions in the positive direction, N, E, S, W.

I alluded in the last Report to the reduction of the Photographical Records of readings of Dry and Wet Thermometers from 1848 to 1868, and to the arrangement of the results in various tabular divisions, and as connected with various meteorological conditions of the atmosphere. This work had been effected under the superintendence of Mr. Glaisher. My examination of the abstracts of the results was long delayed by the unceasing pressure of employment. I have at length examined and arranged them, and, with the assistance of Mr. Ellis, have prepared an Introduction. In the progress

of the work, other subjects of examination have presented themselves. One is, the reduction of the photographic records of the barometer with reference to diurnal inequality; another is, a similar reduction with reference to lunar tide. These are advancing, and will be finished, I hope, in the present year.

The examination of the readings of the deep-sunk thermometers from 1846 to 1873 has exhibited some laws which had been sufficiently established before this time, and some which were less known. Among the former were the successive retardations of seasons in successive descents, amounting to about four months at the depth of 25 feet; and the successive diminutions of the annual range of temperature. Among the latter is the character of the changes from year to year, which the great length of this series of observations brings well to light. It is found that from year to year the mean temperature of the surface for the year, varying by three or four degrees of Fahrenheit, follows in its changes the mean temperature of the atmosphere for the year; and that the changes of annual temperature are propagated downwards, retarded in phase and diminishing in amount of change, in the same manner (though probably not following the same law) as the season-changes. The inference from this is, that changes of temperature come entirely from the exterior and in no discoverable degree from the interior; an inference which may be important in regard both to solar action and to geology.

I am engaged in tracing the possibility of relation between the irregularities in the annual temperature and the irregularities in the annual produce of corn, but have not yet arrived at any perfectly satisfactory results.

XIII. Printing and Distribution of the Volume of Greenwich Observations:—

The increase in the number of the subjects of report, of which the numerical details are usually bound in one annual volume, makes it convenient to include the account of the state of printing of the whole in one chapter of the Report.

As regards the Ordinary Astronomy; the printing of the Transit section and the various Altazimuth sections for 1874 is finished; but the general printing of the volume has been somewhat delayed, and this has permitted the application of the corrections for inequality of the screws of the Transit-circle-micrometers in the star-catalogue. A small part of the Circle Observations is not yet touched, and no part of the section of Astronomical Results is printed. The whole of the manuscript for 1874, excepting that of the Introduction, is in the printer's hands.

The Photographic Section, in which are given the areas of solar spots and faculæ for 1873 and 1874, is nearly complete. In the Spectroscopic Results, I have decided

to defer the publication of the few observations made in 1874 to the volume for 1875; the manuscript is, however, ready for press.

The Magnetical and Meteorological Results are entirely printed for 1874. (The Visitors will remember that the details of these observations are not usually printed.)

The Magnetic part contains detailed measures of the magnetic photographs on five days of magnetic storms; and mean diurnal inequalities of declination, horizontal force, and vertical force, in each month, as deduced from all other days of 1874. The values of the disturbing magnetic forces which these imply, in the three rectangular directions, are expressed in terms of Gauss's absolute unit as measured on the metrical system. Reductions and results are given for each individual observation of dip and of horizontal force.

The Meteorological part contains the daily results of the barometer, four thermometers, both anemometers, and a pluviometer; with general observations of electricity, clouds, and weather, reading of the deep-sunk thermometers, and records of the temperature of the water of the Thames.

The Introduction to these Results is not yet printed.

For the year 1875, the whole of the manuscript of the Transits, Zenith Distances, and Altazimuth observations (with tabular calculations of the last), have been sent to the printer. A few sheets have been printed.

It is usual to include, in the printed volume, the sheet of tabular Report on the rates of Chronometers on Competitive Trial, and the Annual Report to the Board of Visitors.

The number of copies of the Annual Volume of Greenwich Observations and its parts, printed in late years, is as follows:—

Of the Volume, including everything	300 copies.
Separate copies of the Astronomical Results (to include in future the Photographic and Spectroscopic Results) . . .	150 ,,
Separate copies of the Magnetical and Meteorological Results .	250 ,,
Separate copies of the Report on Chronometers . . .	700 ,,
Separate copies of the Report to the Board of Visitors . .	700 ,,

When a Catalogue of Stars from the observations of several years has been prepared, it is necessary to print a larger number of separate copies. The impressions of our two last catalogues are nearly exhausted; and attention will be given to this in fixing the number for the next catalogue.

A portion of the impression is sent to the Royal Astronomical Society, and the greater part of the remainder is distributed; the large Volume as much as possible to institutions of a permanent character, the separate copies in large part to individuals. A few copies are sold through H. M. Stationery Office.

The results of observations of the small planets are communicated every quarter to M. Le Verrier. Observations of Jupiter's Satellites, &c., are transmitted occasionally to the Royal Astronomical Society. Daily meteorological results are given to M. Le Verrier, to the United States War Department, to the Registrar General, to the Meteorological Office, and to some daily newspapers; they are also exhibited to the public, on the walls of the Observatory Inclosure.

XIV. Chronometers, Time Signals, Regulations of External Clocks, Operations for Longitude :—

There are now in the Chronometer Room 161 chronometers, of which 128 are box-chronometers, 25 pocket-chronometers, and 8 deck-watches.

Of these, 47 are the property of chronometer-makers, being placed here on the annual competitive trial; the others belong to the Government, and have been either returned from service for examination and repair, if necessary, or are awaiting issue to ships of the Royal Navy after having been repaired by the maker. All such chronometers are compared at least once a week, and at some time during their period of rating are tried for at least three weeks in a temperature of nearly 100° Fahrenheit. The competitive chronometers, as well as any Government chronometers which appear to require it, are compared every day; they undergo two trials in heat for periods of four weeks each, and are also rated in different magnetic positions.

The supplementary compensation mentioned in the last Report has been applied with success to a number of chronometers, and in future all chronometers sent in to the annual trial are to be so fitted. From experiments which have been made with one of the chronometers, to which the compensation-piece has been applied, it is found that the final adjustment of the compensation can be made with certainty at the Observatory; and it will thus be unnecessary to return a chronometer to the maker, when, as has happened in a large proportion of cases lately, there is a slight error in the compensation.

The first six chronometers in the competitive trial of last year were on the average somewhat superior to those of 1874; the chronometer at the head of the list, in particular, being a very fine one.

The Greenwich Time-ball has been regularly dropped automatically on every day throughout the year, with the exception of 7 days when the violence of the wind made it imprudent to raise the ball, and of 2 days when there was accidental failure.

The Deal Time-ball was not raised (on account of high wind) on 10 days, and was not dropped or was erroneously dropped (by telegraph signals) on 17 days. On 328 days it was dropped correctly, though on 52 of these the galvanic current was too weak to release the trigger without the assistance of the attendant, principally from the defective insulation of the wire, which has now been to a great extent overcome by increase of the battery-power.

No change has been made in the system of time-signals, which are distributed to all parts of the country by means of relay-action at the Central Office of the Post Office Telegraphs.

The regulation of the Lombard Street Clock by galvanic current from Greenwich has worked satisfactorily during the past year, and the Westminster Clock has maintained its high character, its error having been below one second on 273 days during the year to which this Report refers.

No further action has been taken in the proposed telegraphic determination of the longitude of the Dublin Observatory. Recently Prof. Oppolzer has proposed to determine, by direct telegraphic communication, the longitude of Vienna, and has arranged a very complete plan of operations for this object, which I hope will be carried out shortly.

XV. Personal Establishment:—

No important change has been made since my last Report. The following statement of the staff of the Observatory will probably be sufficient:—

Mr. Christie, Chief and Confidential Assistant, and exercising full power in the absence of the Astronomer Royal.

In the Astronomical Department;

Mr. Dunkin, Superintendent of Supernumerary Computers, especially of those engaged in the Transit-reductions and in the advanced computations.

Mr. Lynn, Superintendent of the Altazimuth, charged with the care of that instrument and with the reduction of the observations, usually assisted by one Supernumerary.

Mr. Criswick, superintending the care, rating, receipt, and issue of Chronometers, and the official correspondence thereon; and the management of time-signals. Mr. Criswick also has the custody of Stationery, and at the four quarters of the year arranges the Money Accounts. One Supernumerary is appropriated to his assistance.

Mr. Downing, principally employed on the Library and the Manuscripts, which absorb much time.

Mr. Thackeray, employed on the reduction of the Zenith-distance-observations made with the Meridian Circle, and on the work of the Chronograph.

The four gentlemen last mentioned are liable to be called on at any time to make observations with any of the astronomical instruments, and are, in fact, so employed to the utmost practicable demand on their strength.

Six or seven young men, the terms of whose employment rest entirely on my discretion, are attached as Supernumerary Computers to this department. They are easily induced to practice astronomical observations, and become trustworthy observers, capable of relieving the pressure on the regular assistants.

In the Magnetical and Meteorological Department,—

Mr. Ellis is responsible for the superintendence of every part,—the buildings, the instruments, the observations, and the reductions.

Mr. Nash is subordinate to Mr. Ellis, and, in the absence of Mr. Ellis, manages the department.

Four Supernumerary Computers are connected with this department. The number will probably be diminished when the Barometric Reductions to which I have alluded shall be terminated.

In the Photographic and Spectroscopic Department,—

Mr. Maunder conducts all the work in this office. He is assisted by one Supernumerary. In the course of his operations, he is practically the superintendent of the Great Equatoreal.

Three inferior servants (gate-porter, watchman, labourer,) and a carpenter (who, though under no regular engagement, becomes in fact Clerk of Works), are a part of the permanent establishment of the Observatory. It is impossible in the present course of employments to dispense with the constant presence of workmen.

It is my continued endeavour so to make myself acquainted with the current work of Assistants, Servants, and Workmen, that I may possess a sufficient check of all,

for effectively carrying out the scientific objects of the Observatory, and for due attention to economy. This is secured in great measure by a system of Reports, daily, weekly, or occasional.

XVI. Extraneous Work:—

I first advert to the operations connected with the Transit of Venus, carrying on the history from the last Report.

The observers all returned in the course of the last summer, and I am happy to say without death or accident. I have to lament, however, the subsequent decease, on the West Africa station, of Lieut. C. Corbet, R.N., an officer who had my highest confidence. The chiefs of stations, and other observers, passed some time at Greenwich, engaged in the registering or recording of their observations; but all have now departed, with the exception of Captain Tupman, R.M.A., who is charged with the entire work of reduction, and with the superintendence of four junior computers within the Observatory, and several external to it; and of Lieut. Neate, R.N., who has nearly completed the Rodriguez reductions. The instruments also have all returned, with the exception of those from Kerguelen, which I have already mentioned as being lodged at Simons Town. At the moment of issuing this paper I learn that the Admiralty have taken efficient measures for the prompt return of these instruments.

In the astronomical part of the reductions, there has been great labour and difficulty in the determination of local sidereal times; some books of observations required extensive transcription; some instrumental errors are still uncertain; the latter determinations have perplexed us so much that we are inclined to believe that, in spite of the great facilities of reduction given by the transit-instrument, it would be better to rely on the Altazimuth for time-determinations. Generally, however, the local times are completed, except in Owhyhee, and the greater part of clock-comparisons and chronometer-comparisons are reduced. In the geographical longitudes little advance has been made; the errors of the Moon's tabular place, as determined at four observatories, are under consideration. The Greenwich times in District A (Egypt) were, however, determined long ago (by use of the long telegraph wire, as explained in the last Report). Various printed forms have been prepared for the computations of tabular local parallaxes, &c., and a complete ephemeris of the geocentric places, parallaxes, and semi-diameters, for every ten seconds of Greenwich sidereal time through the Transit, has been printed and circulated.

In the photographic part, I have confined my attention entirely to measures of the distance between the centers of the Sun and Planet; and, using an instrument arranged

specially for that purpose, have measured on the photographic images the distance of the four limbs in the line passing through the center of the Sun's disk, by reference to a scale of millimètres with microscopic-micrometer. The first operation was to ascertain the corrections due to the small errors of the subdivisions of the millimètre scale. The next more complex step was—(1) to photograph Mr. De La Rue's scale by planting the photoheliographs in succession at a place distant about 1,700 feet; (2) to examine the errors of division of Mr. De La Rue's scale; and thus (3) to measure the distortion of the photographic images. The measuring of the photographs of the Sun and Venus was, logically, the third operation. All these were done by Mr. Burton. The first part is entirely reduced, the second is partially reduced, the third is not corrected for the errors of scale and distortion. When finished, this operation will give measures in terms of the Sun's apparent semi-diameter. The photographs taken in India and Australia have been received, and have been measured with the same instrument; and I hope to make arrangements for including all in the same general system of reductions.

The point to which I next refer is the progress of the Numerical Luuar Theory.

With a repetition of grant from the Treasury, I have usually maintained four junior computers on this work. The progress, though considerable, has not been so great as I had hoped. The retard has arisen from two causes, both due to the excessive personal pressure upon me during the whole year.

The first is the necessity of extending the calculations by one or two decimals. The necessity for this, in some degree, had been perceived from the first, but it was found imperative, on more careful consideration, to include a greater number of terms than I had anticipated.

The second is that at times, when I could not watch every step, my computers, unacquainted theoretically with the arithmetic of sines, had committed some serious errors. Their numerical computations are, generally speaking, correct; so that the restoration to proper order will not be very difficult.

The magnitude of these calculations, intended to secure exactitude to $10^{-7} = 0''{\cdot}02$, may be judged from the statement that in one of the terms, on the perturbed side of the equation, the number of arguments of inequalities is about 270, and that this is produced by repeated multiplications of one series of the same class by another series of the same class.

In the perturbing side of the equations, considerable progress has been made. I am not able yet to assert its immunity from error.

The treatment of the symbolical corrections has not advanced.

The personal occupation of my time, produced by references on scientific matters extraneous to the Observatory, has been in the last year somewhat greater than usual.

XVII.—General Remarks:—

The year for which the history of the Observatory is given in the preceding Report has been one of unusual labour. The demands which this implied upon the efforts of the officers of the Observatory have been met in the best spirit. And I am bound to regard with gratitude, on the part of the Observatory and myself, the orderly and zealous conduct of every Assistant connected with the Observatory.

This labour, however, is not without fruits to counter-balance it. Faults of a totally unsuspected character have been detected in one instrument; and, I trust, have been perfectly corrected. After the warning which they have given, the probability of a recurrence is greatly diminished. In another, the methods for an important instrumental adjustment have been facilitated, and thereby rendered more certain of frequent application. In a new class of instruments, the experience in the numerous causes of error and the practical forms of remedy has given to the Chief Assistant, who principally has superintended the use of those instruments, an accurate acquaintance with them, possessed by few other observers. In the theory which I am myself promoting, though time has been lost, accuracy has been gained. Material matters, such as the care of manuscripts and library, and of the still lower subjects of buildings and grounds, have not been neglected. Friendly communication has been maintained with other Observatories.

Upon the whole, I trust that the present position of the Observatory will be regarded by the Visitors as satisfactory.

G. B. AIRY.

Royal Observatory, Greenwich,
1876, *May* 11.